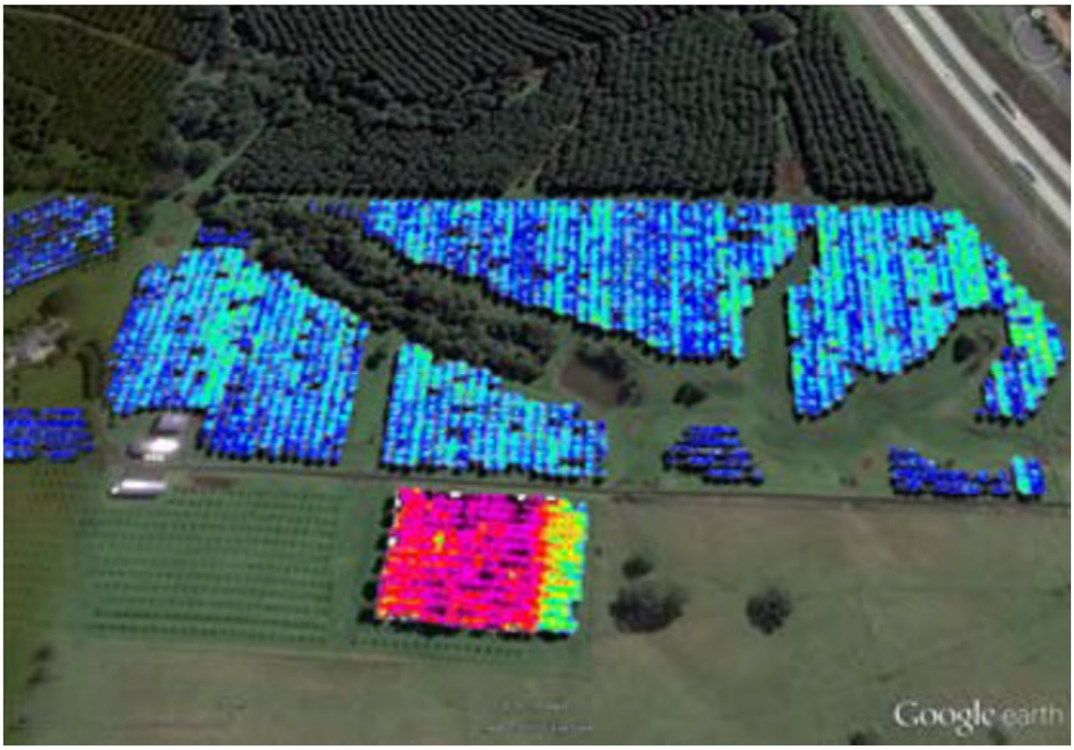
Using LIDAR to measure the impact of tree height on yield and kernel recovery in mature macadamia orchards



Agri-Science Queensland Innovation Opportunity

June 2018

Queensland Government

This publication has been compiled by Grant Bignell and Shane Mulo of Horticulture and Forestry Science, Agri-Science Queensland, Department of Agriculture and Fisheries.

Summary

As the macadamia industry has matured, a presumed relationship between tree age and declining yields has been identified as a potential threat to the industry's future sustainability. Despite some evidence to support performance decline in older trees, there is evidence that some farms continue performing well despite tree age.

There is both anecdotal evidence and logic to suggest that yield declines in older orchards may be related to tree height rather than age. Clarifying relationships between tree height and productivity could provide the quantitative information required to inform growers about the value of tree height reduction strategies in older orchards. This project aimed to source existing Light Imaging, Detection and Ranging (LIDAR) tree height data for a sample of mature macadamia orchards and relate this to annual yield and kernel recovery data sourced from the macadamia benchmarking project (MC15005).

LIDAR can be used to rapidly collect detailed information on tree or canopy height. For this project, existing LIDAR data was sourced and processed by an external partner (GES Mapping) for nine orchards in the older NSW Northern Rivers macadamia growing region. This canopy height information was then related to whole-orchard yield and quality data from the project "Benchmarking the macadamia industry 2015-2018".

The project did not find clear relationships between macadamia canopy height and yield or quality, partly due to the low number of suitable orchards available for analysis. This low number was due to the spread of LIDAR mapping over many years, as well as a difference in the resolution of the benchmarking and LIDAR data sets. Also affecting the ability to identify relationships was the age of relevant LIDAR data. However clear understanding of how best to overcome these limitations was gained and practical recommendations made, including collaboration between current macadamia research projects.

Table of contents

Table of figures

Background

Many older macadamia orchards are seeing declining yield and kernel recovery, yet industry data shows that neither tree age nor planting density are strongly correlated with orchard productivity. There is anecdotal evidence to suggest that such declines may be related, at least in part, to tree height. A logical explanation for this is that very tall trees (around 10 m or higher) can result in reduced light penetration into the canopy and thus exposed orchard floors due to lack of ground cover. Tall, dense canopies can also lead to poor spray coverage and thus high rates of pest and disease damage.

Industry assumptions have included tree age causing reduced production. Row interlacing is expected at heights of approximately six metres, and a reduction in light availability and other factors may affect the levels of saleable kernel in trees around this height. However orchard management case studies (macSmart video 2017) have illustrated that tree age is not necessarily detrimental to production, and older trees can be brought back to competitive yields through effective canopy management practices. No clear yield declines with age can be seen in the full set (all regions) of macadamia benchmark data for farms from 2009 to 2016 (Figure 1).

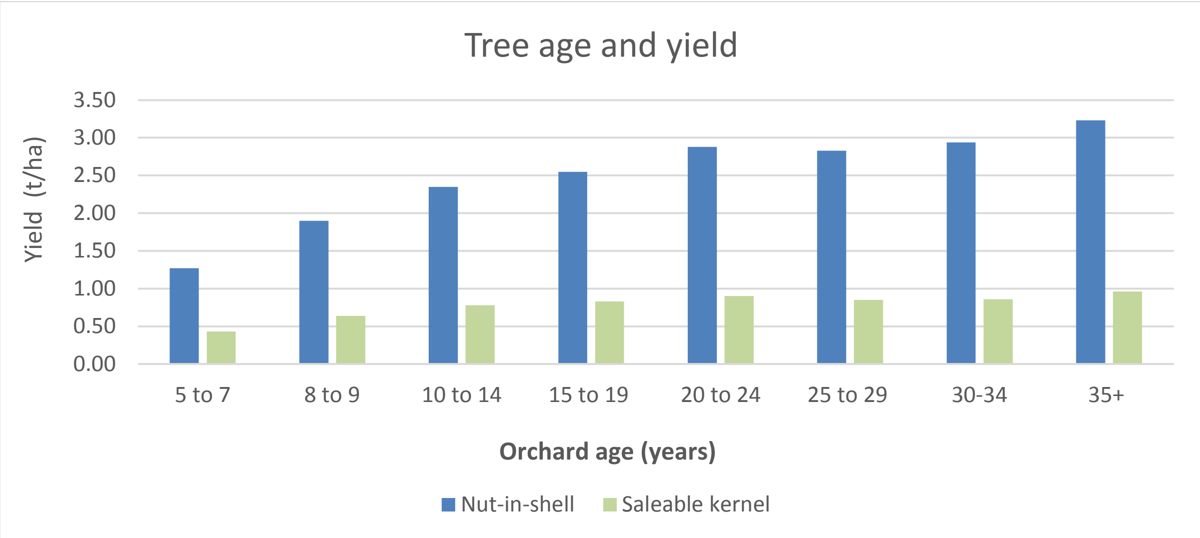


Figure 1. Relationship between tree age and saleable kernel yield among benchmarking orchards of all growing regions from 2009 to 2016

Investigation of the effect of canopy height on yield is thus important, but canopy height control is costly and time consuming. Managers who do reduce orchard height face the challenge of restoring and maintaining long-term orchard productivity whilst avoiding substantial reductions in short term yield and cash flow. Some growers have developed successful strategies to reduce tree height, however many other growers are yet to attempt height reduction. The industry has examined tree training (i.e. central leaders versus bush) and pruning styles (i.e. hedging). However the current industry practices, resulting in tall trees with shading and reduced production except for the upper most canopy regions, indicate that growers are nervous about making canopy management decisions that may result in extended production loss.

Thus the impact of canopy management is a hot topic for the macadamia industry. While quite a lot of research has been conducted in this area (McFayden *et al.* 2005; 2012, Wilkie *et al.* 2009; 2010, Olsen *et al.* 2011), the industry is no closer to having standard operating procedures for pruning that produces consistent results.

Light Imaging, Detection and Ranging (LIDAR) is a technology that is gaining momentum in the macadamia industry. LIDAR uses light in a similar fashion to radar using radio waves or sonar using sound; sending out pulses of light from a sensor and recording the time it takes to be reflected. The data is recorded in an x,y,z point cloud formation using Global Positioning System navigation information that can be transformed into three dimensional maps. LIDAR has proven application in the management of water movement, planting, and erosion management in the macadamia industry (Bright *et al.* 2017).

The information provided by LIDAR however may have wider application; used to measure tree or canopy height it could, along with other existing data, assist in clarification of any effect that tree height has on yield or quality. The project “Benchmarking the macadamia industry 2009-2018” (MC15005) has collected orchard yield, quality and planting data since 2009. More than 56% of industry production is now covered by the study. Benchmark results show that yield varies significantly between mature orchards in any given season, ranging from one to six tonnes per hectare. With such variability, medium to large sets of data may be needed to show relationships between yield and orchard characteristics such as height.

Project Objectives

This project aims to source existing LIDAR tree height data for a sample of mature orchards and relate this to concurrent yield and quality data. These analyses would provide an objective and more accurate assessment of the relationship between productivity and tree height in mature orchards than is currently available.

Identifying relationships between tree height and productivity would provide quantitative information which, combined with existing case studies of successful tree height reduction strategies, could help assess the worth of tree height reduction in older orchards. It could also guide earlier adoption of effective, sustainable canopy management strategies among younger orchards, which may substantially reduce costs and improve productivity and sustainability across the macadamia industry.

Methodology

Orchards selected for this study were needed with tall macadamia plantings, around ten years or older. They also had to have already been mapped by LIDAR, and to have been involved in the macadamia benchmarking project in the year around that LIDAR mapping.

The New South Wales and Queensland governments have been collecting LIDAR data since 2009 (Howard 2015). Involvement of a specialist in LIDAR data access and analysis, including access to software needed for LIDAR data processing, is important to obtain the best results from the data. Relevant existing LIDAR data was collated through collaboration with Mr. Bob Howard (of GES Mapping) and anonymous macadamia benchmarking participants. LIDAR data was collated for orchards in a number of different macadamia growing regions. However, due to differences in the year of LIDAR capture (2009, 2016, 2017) and the method of capture (drone versus plane), comparisons could not be made between all orchards and production years covered by this data.

The largest group of orchards with plantings ten years or older that could be logically compared to each other was made up of nine orchards in the Northern Rivers region of New South Wales (NRNSW). These were covered by plane-collected LIDAR maps from 2009 and also participated in the project “Benchmarking the macadamia industry 2009-2018” in 2010. (The height data from these 2009 maps was matched to the benchmarking information on the crops developing at that time, i.e. crops harvested in 2010.) Orchards 5, 6, 7 and 9 of this study group are under the same management, which would link their yield and quality.

Processing of LIDAR measurements by GES Mapping included eliminating from the data set other crops or native vegetation located between macadamia blocks. LIDAR data was received as KPI files with data reported by orchard block. The KPI files illustrated canopy height using a colour scale. The LIDAR data as received provided average canopy heights (with standard deviations), rather than tree heights as originally stated in the project proposal, due to the substantial differences in tree spacing in the macadamia industry. These spacing differences lead to inaccurate tree height data unless a tree location map is available.

KPI files were loaded onto Google Earth (

Figure 2). Average block elevation was used as canopy height above ground. Block sizes were used to produce a weighted average canopy height for each orchard, to take into account tree age, variety or site conditions.

The macadamia benchmarking project provided information on tree age, saleable kernel, and reject kernel recovery for each orchard in the data set. Data collected by the macadamia benchmarking project is recorded as one set of yield and quality figures for the whole property. This data is not broken down into yield by block or variety.

Orchard canopy heights were ranked, and then graphed with productivity and quality indicators, including tonnes of NIS, saleable kernel per hectare, and reject kernel levels. These graphs were used to make visual comparisons between the trends in tree height and yield or quality trends. Data from all NRNSW benchmarking orchards (i.e. orchards included in this study as well as all others in the same region) was also graphed, to examine relationships between tree age and nut quality, and changes in tree age distribution in the years since the LIDAR data was collected.

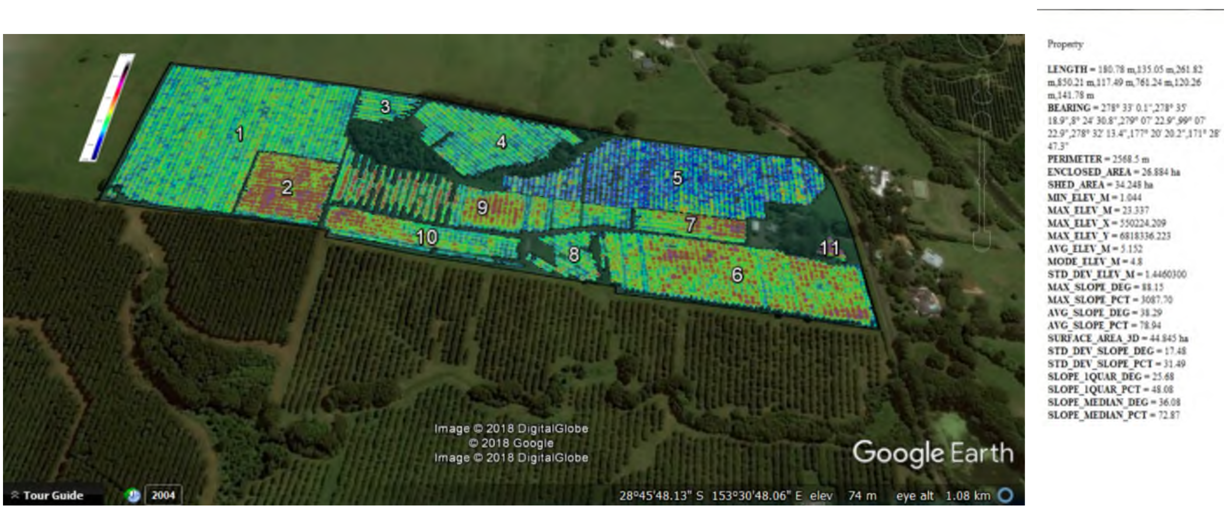


Figure 2. Sample LIDAR results from GES Mapping.

Results

The comparison of tree height with tree age (Figure 3) showed they tended to increase together, as would be expected, although the relationship was not linear. Site effects, varieties or management strategies could also be affecting tree height and complicating this relationship.

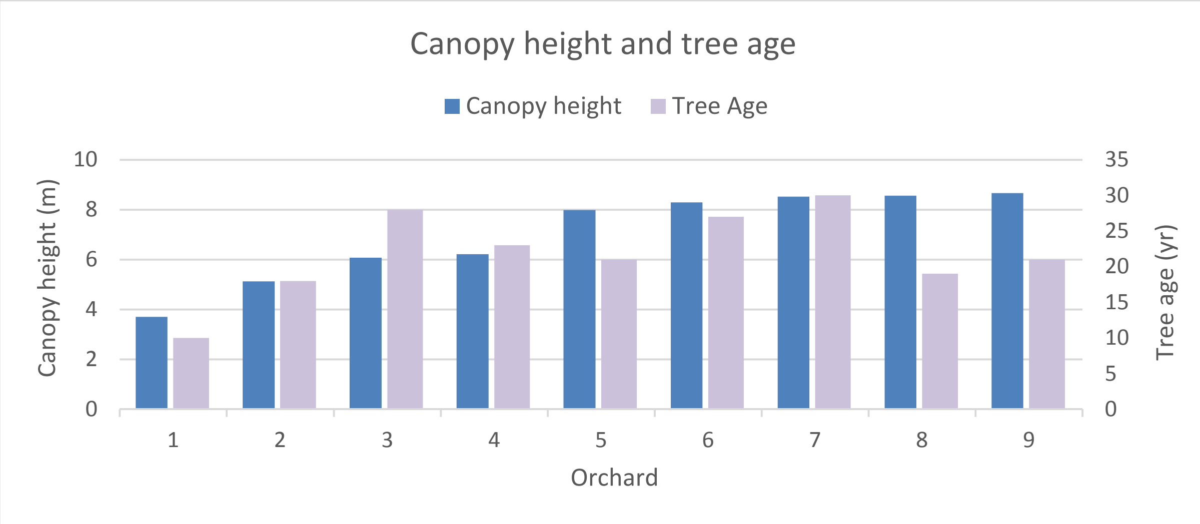


Figure 3. Canopy height and tree age of LIDAR-measured orchards

Comparisons of tree height with nut-in-shell yield (Figure 4) and with saleable kernel (Figure 5) indicated a decline in yield and quality between tree heights of around five to eight metres, after which the orchards all had similar heights and yields.

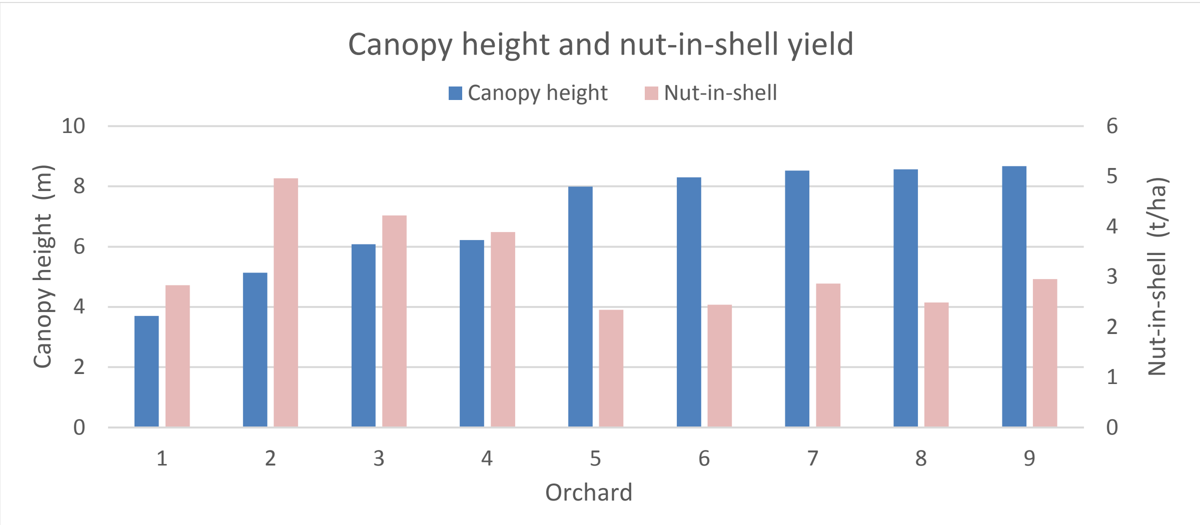


Figure 4. Canopy height and nut-in-shell yield of LIDAR-measured orchards

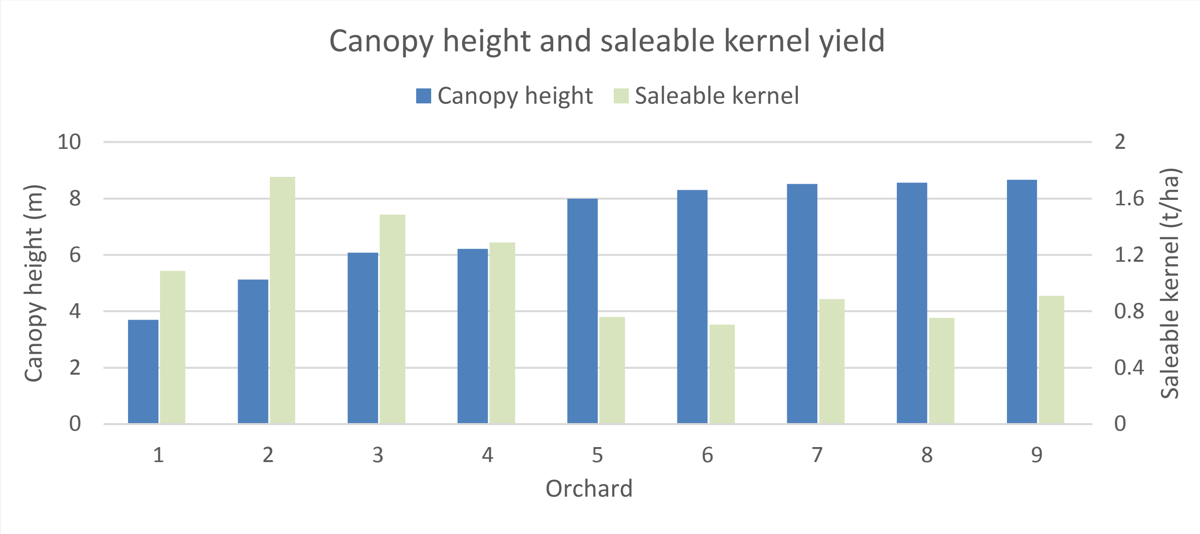


Figure 5. Canopy height and saleable kernel yield of LIDAR-measured orchards

Figure 6 shows reject kernel levels alongside tree height increase. It shows that orchards with taller trees generally had lower levels of reject kernel. This outcome is the reverse of what had been expected, as increased tree height is thought to reduce the ability to effectively manage the top of the canopy for pests and diseases, and this could increase reject kernel levels. Benchmarking project information from the 2010 season about reject kernel and tree age (Figure 7) only partially supports this theory; trees 26-33 years old had higher reject levels than trees aged between 16 and 25 years, but had lower levels than trees younger than 16 years.

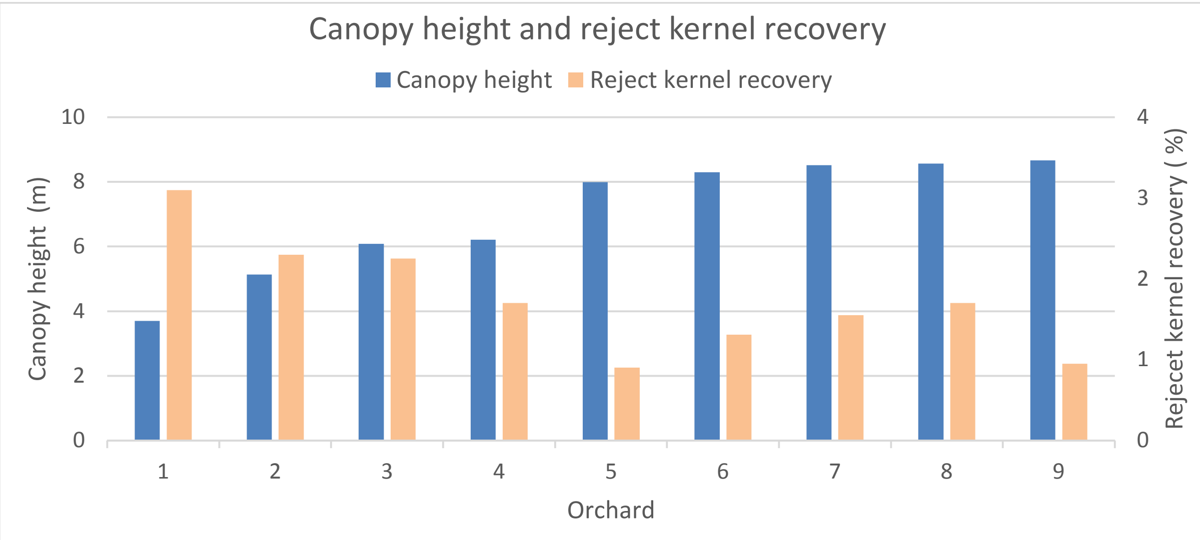


Figure 6. Canopy height and reject kernel levels of LIDAR-measured orchards

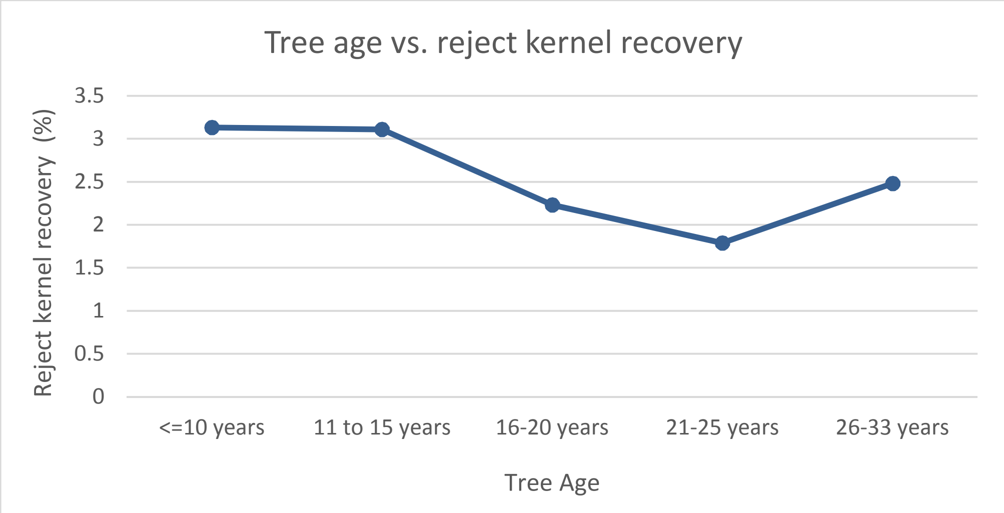


Figure 7. Relationship between tree age and reject kernel recovery of 2010 benchmarking orchards

Industry benchmarking data shown in Figure 8 indicates that in 2010 only 24% of macadamia trees in the NSW Northern Rivers were in the age group of 25 years and older - when growers start to experience issues in yield decline (and when trees are expected to be around 8 metres or higher). However now in 2017 45% of trees grown in this region are in this age category.

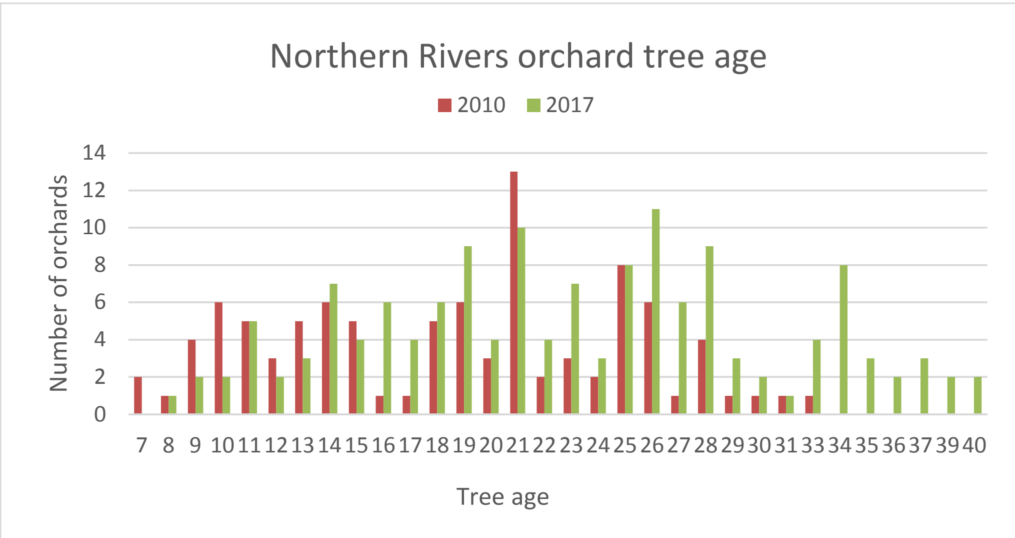


Figure 8. Orchard tree age distribution among benchmarking participants in NSW Northern Rivers region, in 2010 and 2017

Conclusions, significance and recommendations

Relating macadamia tree height to yield and quality data was an exercise in evaluating the potential for LIDAR to provide useful information to the macadamia industry's questions about tree height. This project expected to address the current macadamia industry issue of tall trees in orchards and declining yields. However the most relevant LIDAR data was collected in 2009 (8-9 years ago), when tree height in the study region was lower and fewer orchards were in the height range suspected to be yield limiting. No simple or clear relationship between macadamia orchard height and yield or quality was found.

The importance of maintaining the bigger picture of macadamia orchard management, including factors such as light interception, soils, nutrition, and water management, has been raised as part of this work and is acknowledged. Canopy volume may be a more relevant variable to examine than canopy height in future research.

This project has highlighted the opportunities to collaborate with projects such as the "Small Tree High Productivity Initiative" which is collecting data on light interception in different canopy management strategies. Regular collection of LIDAR data at such trial sites could benefit the development of models of macadamia canopy height management and changes in tree architecture, as LIDAR affords a rapid method of collecting detailed information. However the testing of this technology has provided insights into its practicality and relevance to industry - the data cannot fully replace a physical presence in the orchard because ground truthing is also required.

The intermittent nature of historical LIDAR data collection presents problems for comparison between orchards in different growing areas within the same growing season. In addition, the currently available level of detail in benchmarking project yield and quality data is insufficient for making greatest use of LIDAR data detail. Within the benchmarking data, a number of orchards had collected individual block yield data which provided the opportunity to analysis data on a block by block basis rather than a weighted tree height versus one whole orchard yield / quality figure. Unfortunately, nut quality data was not collected at the block level, preventing comparisons with tree height trends. This line of enquiry has highlighted the potential for future studies within the macadamia benchmarking project that look more intensely at data at the block level rather than the whole orchard level. Collection of yield and quality data at a higher level of precision - i.e. at the orchard block level - could produce clearer relationships with the canopy height data available from LIDAR.

With 45% of trees now in the age group that is associated with yield decline, the need to clearly understand any relationship between height and yield or quality is now more pressing, and more orchards are now potential data collection sites.

Key Messages

1. Initial investigations of technologies such as LIDAR are needed before a realistic assessment of the magnitude of opportunities can be made.
2. A level of LIDAR expertise is required to analyse and understand the data. This includes the elimination of objects not relevant to analysis (e.g. native vegetation).
3. The age of available LIDAR data and its relevance to the study need to be investigated before relying on as part of a study. Old data such as that collected in 2010 is not relevant for use in 2017/18 models of canopy height and tree architecture.
4. New South Wales and Queensland governments are still capturing LIDAR data in macadamia growing regions, and so are a source of current canopy height information for further work in this area.
5. LIDAR data can easily provide growers with information about canopy height in metres above ground, while individual tree height data is more difficult to obtain without supporting information.
6. LIDAR is able to capture detailed data quickly, however this data cannot fully replace a physical presence in the orchard as ground-truthing is still required.
7. Check if LIDAR information can be linked to other types of data (e.g. canopy width) to maximise its value and relevance to industry. LIDAR can be used in this way to help calculate canopy volume, which may be a better variable to use in the consideration of macadamia tree canopy management. Connection with other projects collecting ground data could be considered, in order to correlate that information with current LIDAR data.
8. More intense data collection could be considered as part of the macadamia benchmarking project, to provide yield and quality detail at the orchard block level.

Where to next

1. Examine the opportunity for more intensive data collection at the block level in the macadamia benchmarking project.
2. Examine the opportunity for connecting with other projects which are currently collecting ground data and relate that information to current LIDAR data.
3. Access current LIDAR data, by purchasing recently collected sets, and consider the use of drones to collect new data economically.

Budget Summary

EXPENSES	Annual Expense Budget	Actual Expense	Difference
Employee related expenses	8,762.32	5,440.63	3,321.69
Supplies & services	5,364.00	1,589.50	3,774.50
Depreciation, amortisation and deferred	0.00	0.00	0.00
Grants & subsidies	0.00	0.00	0.00
Finance costs	0.00	0.00	0.00
Miscellaneous expenses	0.00	0.00	0.00
Asset writedowns, losses and decrements	0.00	0.00	0.00
Expenses to Government	0.00	0.00	0.00
TOTAL	**14,126.32**	**7,030.13**	**7,096.19**

References

1. Bright, J, Alt, S, Howard, B, Langfield, K (2017) Macadamia integrated orchard management drainage. https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/731462/macadamia-integrated-orchard-management-drainage-2017.pdf

2. Howard, B (2015) LiDAR and its uses in agriculture. Agricultural Innovation Submission 27. http://www.aph.gov.au/DocumentStore.ashx?id=5d9f3c69-f798-4373-b341-d2930be805a0&subId=402975

3. McFadyen, L.M, Morris, S.G, McConchie, C.A, Oldham, M.A. (2005) Effect of hedging and tree removal on productivity of crowding macadamia orchards. Australian Journal of Experimental Agriculture (45) 725-730.

4. McFadyen, L, Robertson, D, Sedgley, M, Kristiansen, P, Olsen, T, (2011) Time of pruning affects fruit abscission, stem carbohydrates and yield of macadamia. Functional Plant Biology (39) 481-492.

5. macSmart (2017) Tree height reduction to maintain productivity. “Benchmarking the macadamia industry 2009 – 2018” project. https://www.youtube.com/watch?v=K0_cP__8GTc

6. Olsen, T, Huett, D, Smith, G, (2011) The production of flowers, fruit and leafy shoots in pruned macadamia trees. Functional Plant Biology (38) 327-336.

7. Wilkie, J.D, Sedgley, M, Olsen,T (2009) A model of vegetative flush development and its potential use managing macadamia (Macadamia integrifolia) tree canopies. Crop & Pasture Science (60) 420-426.

8. Wilkie, J.D, Sedgley, M, Olsen,T (2010) The timing of pruning affects flushing, flowering and yield of macadamia. Crop & Pasture Science (61), 558-600.